Feasibility Study: Economic Modeling of Microgrids

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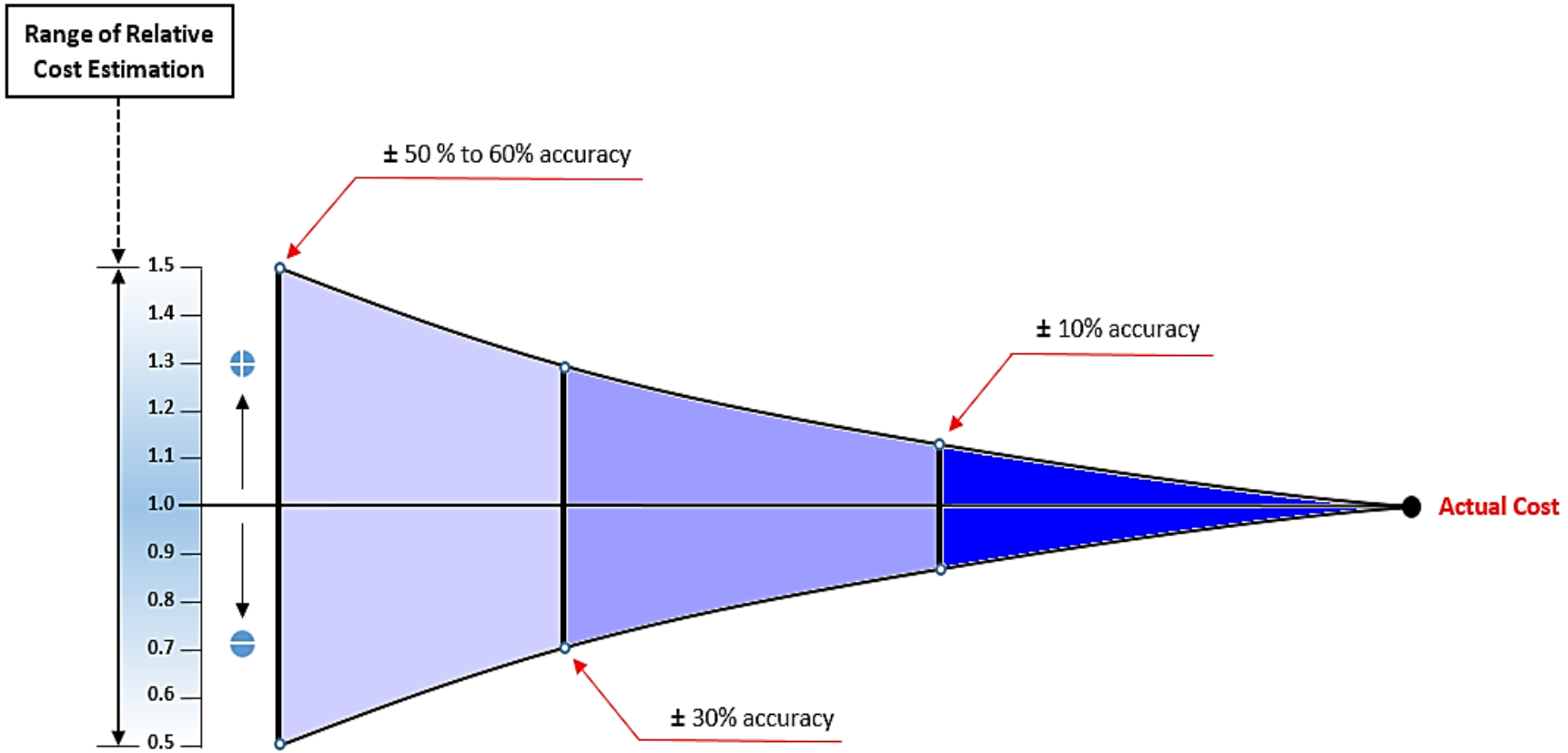
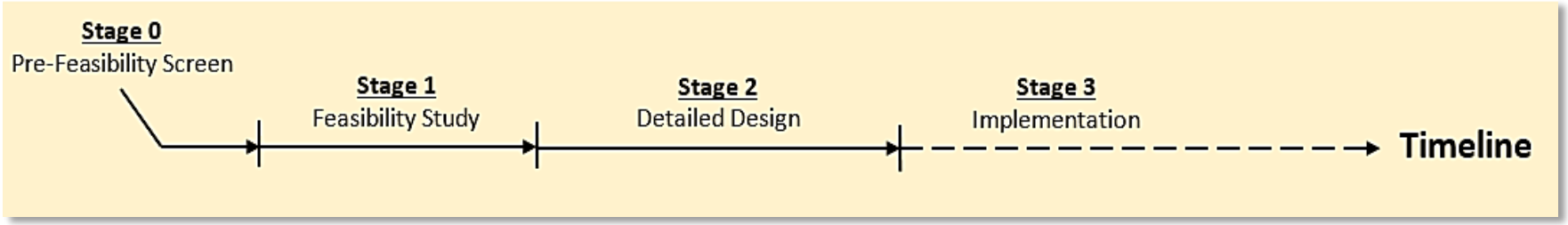
Outline

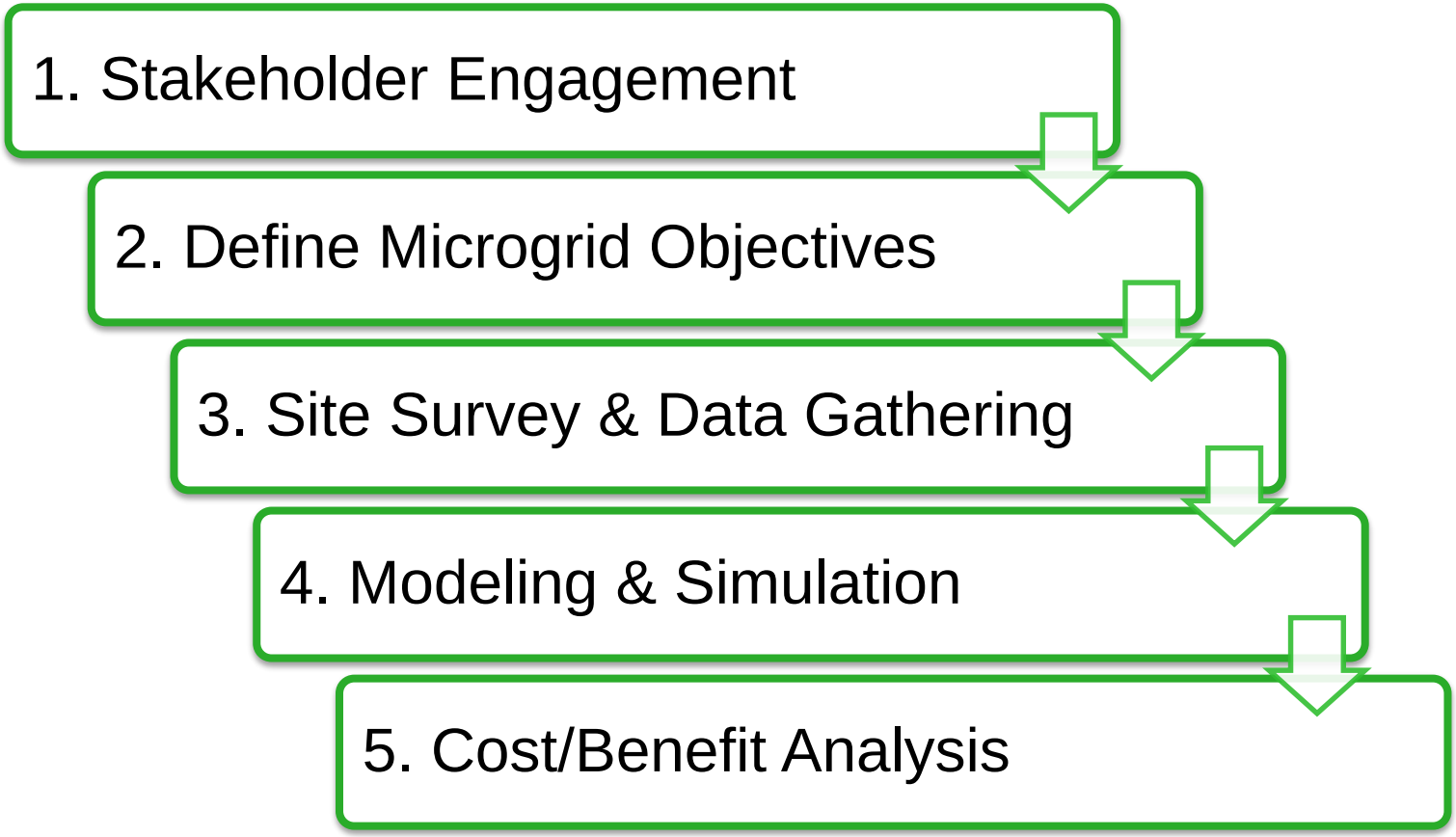
1. Overview: Feasibility Studies
2. Utility Microgrid Sites, Types
3. DER-CAM Modeling Tool
4. Approach to Modeling
5. Sample Case
6. EPRI and LBNL collaboration

Microgrid Technical Design Costs and Evaluations





Phase I: Feasibility Study



Utility Participants and Candidate Target Sites

DOE Project Participants (Level 1)

Supplemental

1. Ameren
2. Central Hudson
3. National Grid
4. United Illuminating
5. Entergy
6. Southern Company
7. TVA
8. EDF
9. Xcel
10. Northeast Utilities
11. Excelon
12. We Energies
13. E.ON
14. SRP

Feasibility Studies (Level 2)

Supplemental

1. United Illuminating (*Bridgeport, CT*)
2. National Grid (*Buffalo Niagara Medical Campus, NY*)
3. Entergy (*Medical Corridor in MS*)
4. EDF (*Concept Grid*)
5. TVA (*Cheeroke Farms*)
6. Peco (*Navy Yard, + 1 site TBD*)
7. We Energies (*Century Park*)

Design Analysis (Supplemental)

1. National Grid
2. ConEd
3. SCE
4. We Energies

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

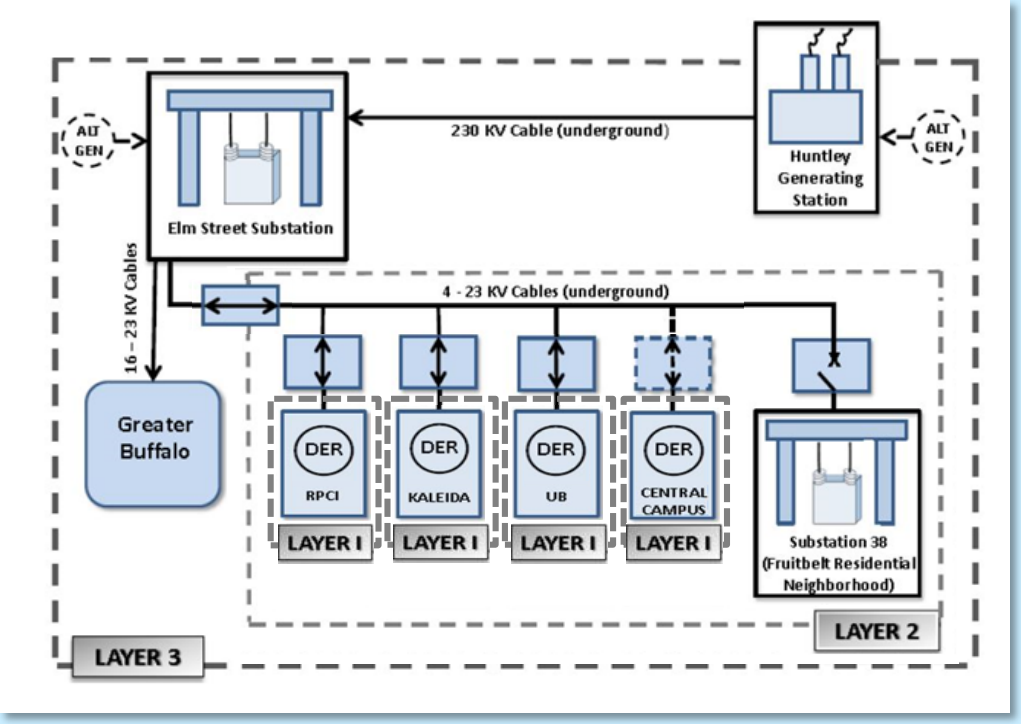
TVA

Cherokee Farm

United Illuminated

Bridgeport

Buffalo Niagara Medical Campus



- Multi-layer microgrid concept
- Many critical health and research services
- CHP likely to be attractive (thermal study being conducted)

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

TVA

Cherokee Farm

United Illuminated

Bridgeport

University of Mississippi Medical Center

- Critical health services, medical schools, research, police
- Cooling centric - a host of centralized chillers serve the campus
- Loss of power would force evacuations during the summer

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

TVA

Cherokee Farm

United Illuminated

Bridgeport

Cherokee Farm Innovation Campus

- Green field project
- Business park, UT research centers, hotel, hospital
- DER test bed – solar PV, batteries, fuel cell, CHP, EV

Utility Microgrid Sites, Types

National Grid

BNMC

Entergy

UMMC

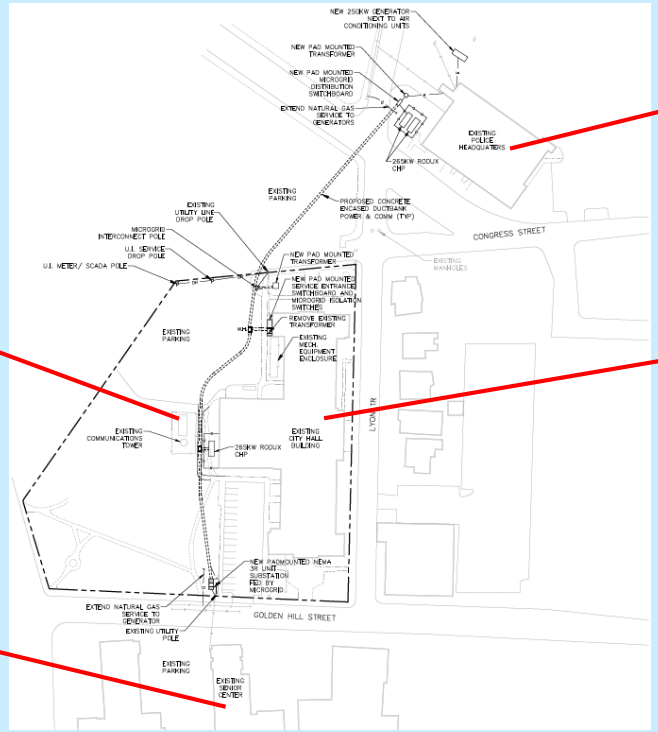
TVA

Cherokee Farm

United Illuminated

Bridgeport

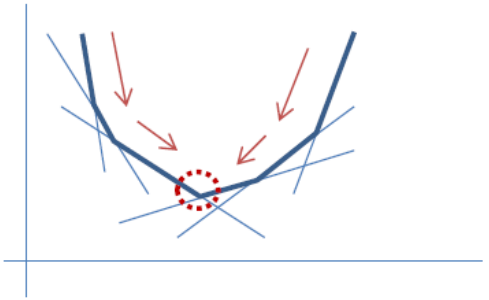
Town of Bridgeport

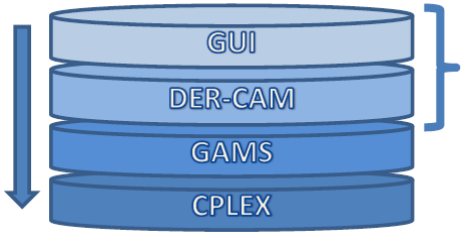


- Brown field project
- Resiliency for emergency services
- Part of a Connecticut D.E.E.P. initiative

DER-CAM Modeling Tool
Distributed Energy Resources Customer Adoption Model

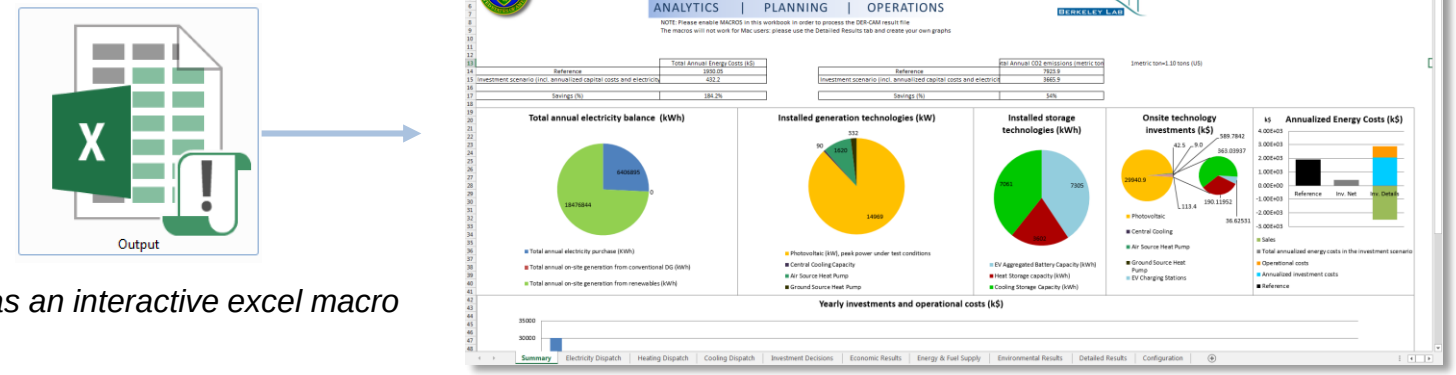
- Developed at Lawrence Berkeley National Lab
- Energy system design using Investment & Planning (I&P) version
- Economic optimization model
  - Objective function
  - Constraints
- Mixed Integer Linear Formulation (MILP)
  - Decision variables can be integer or continuous
  - Objective function and constrains are linear
  - Global minimum is guaranteed
- Platform: GAMS w/ CPLEX





Interface

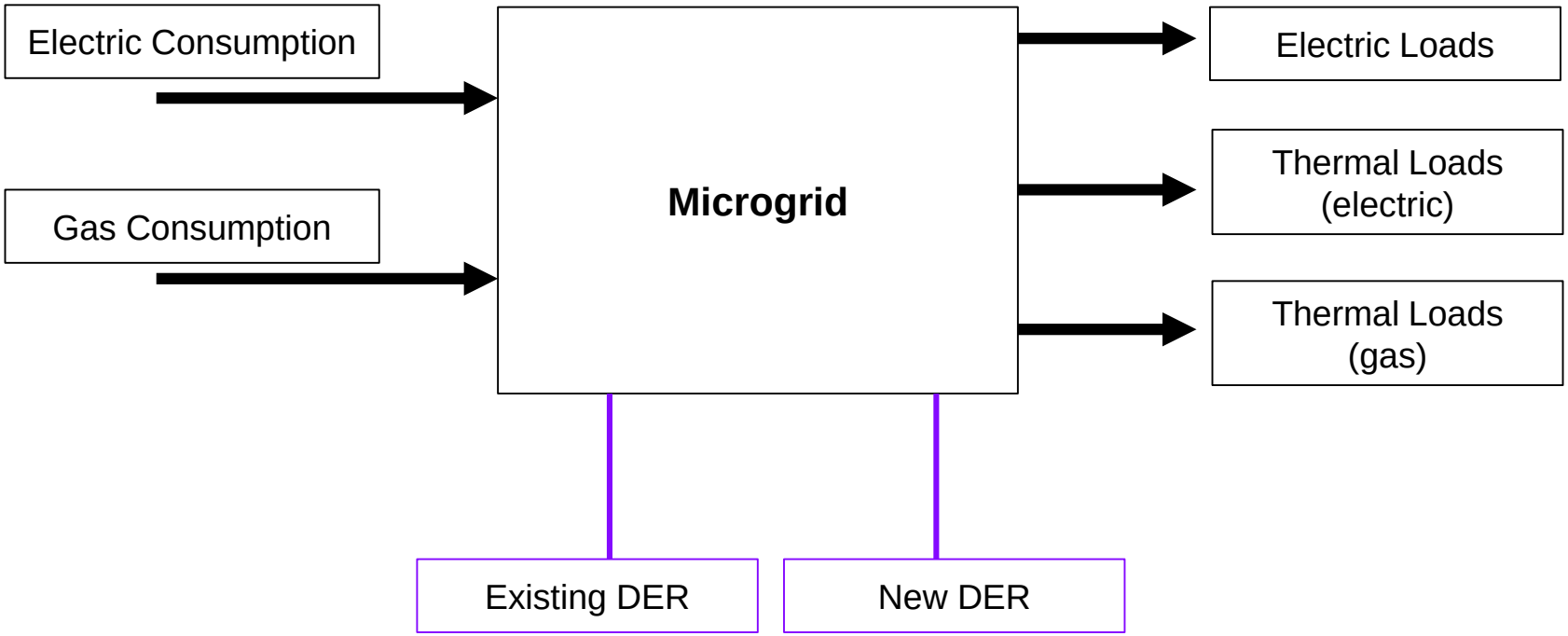
Remote Server Web Interface



Output as an interactive excel macro

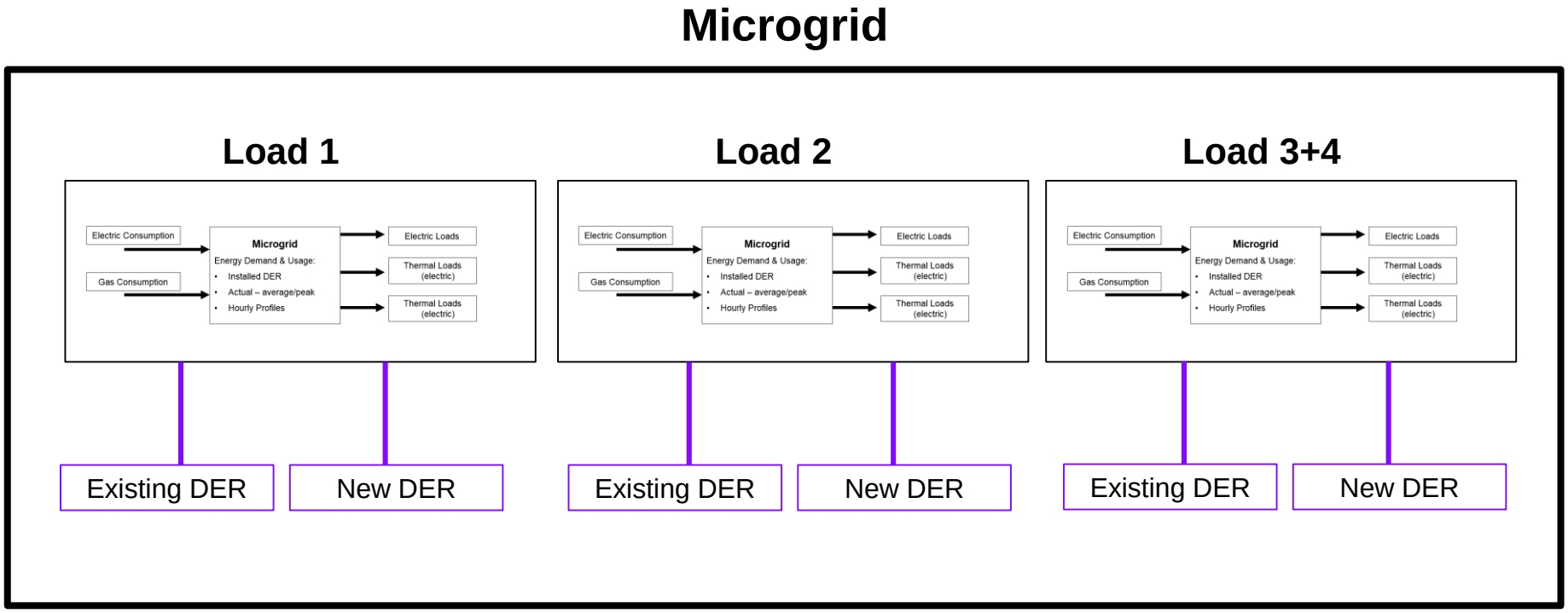
Modeling Approach

- "Black Box"
  - Simple energy-in, energy-out evaluation



Modeling Approach

- Multi-black box approach

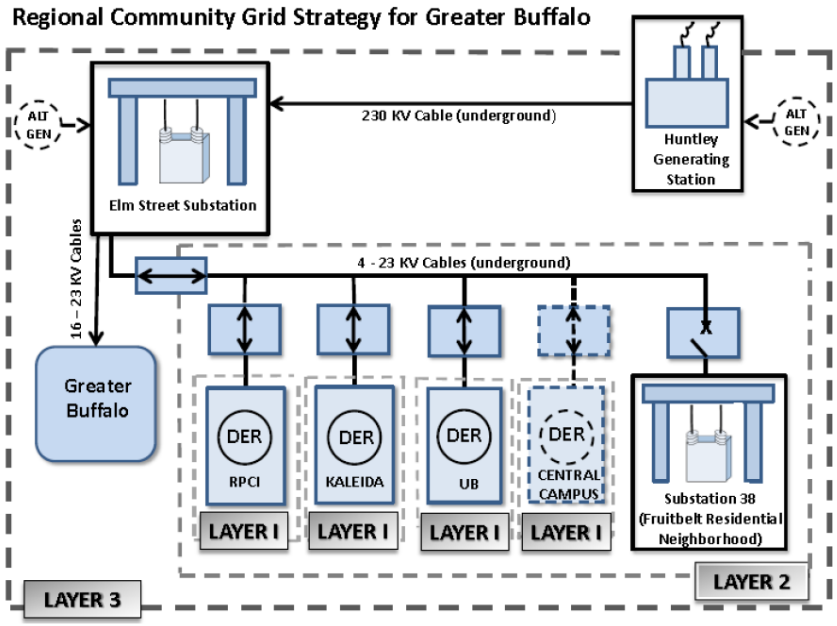


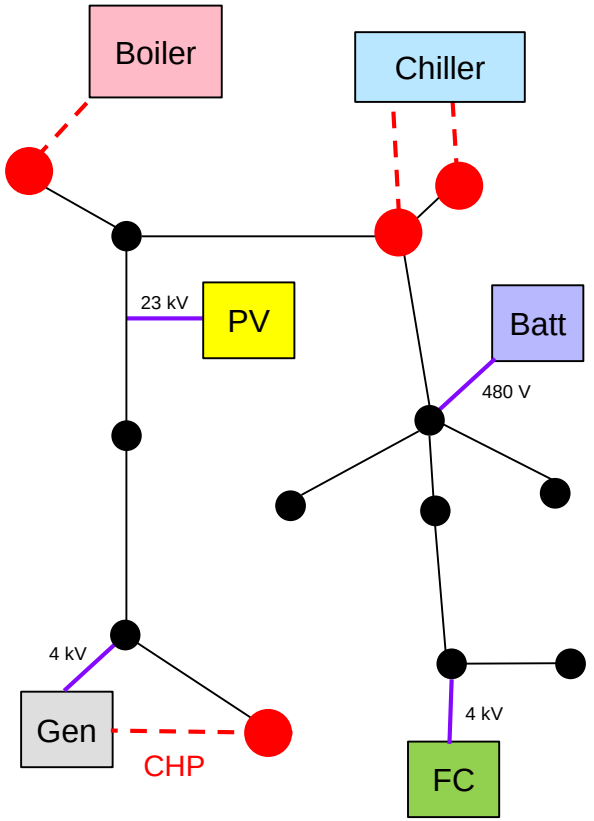
Modeling Approach

- Nodal network
  - Most accurate
  - Also most time and data intensive

System Information

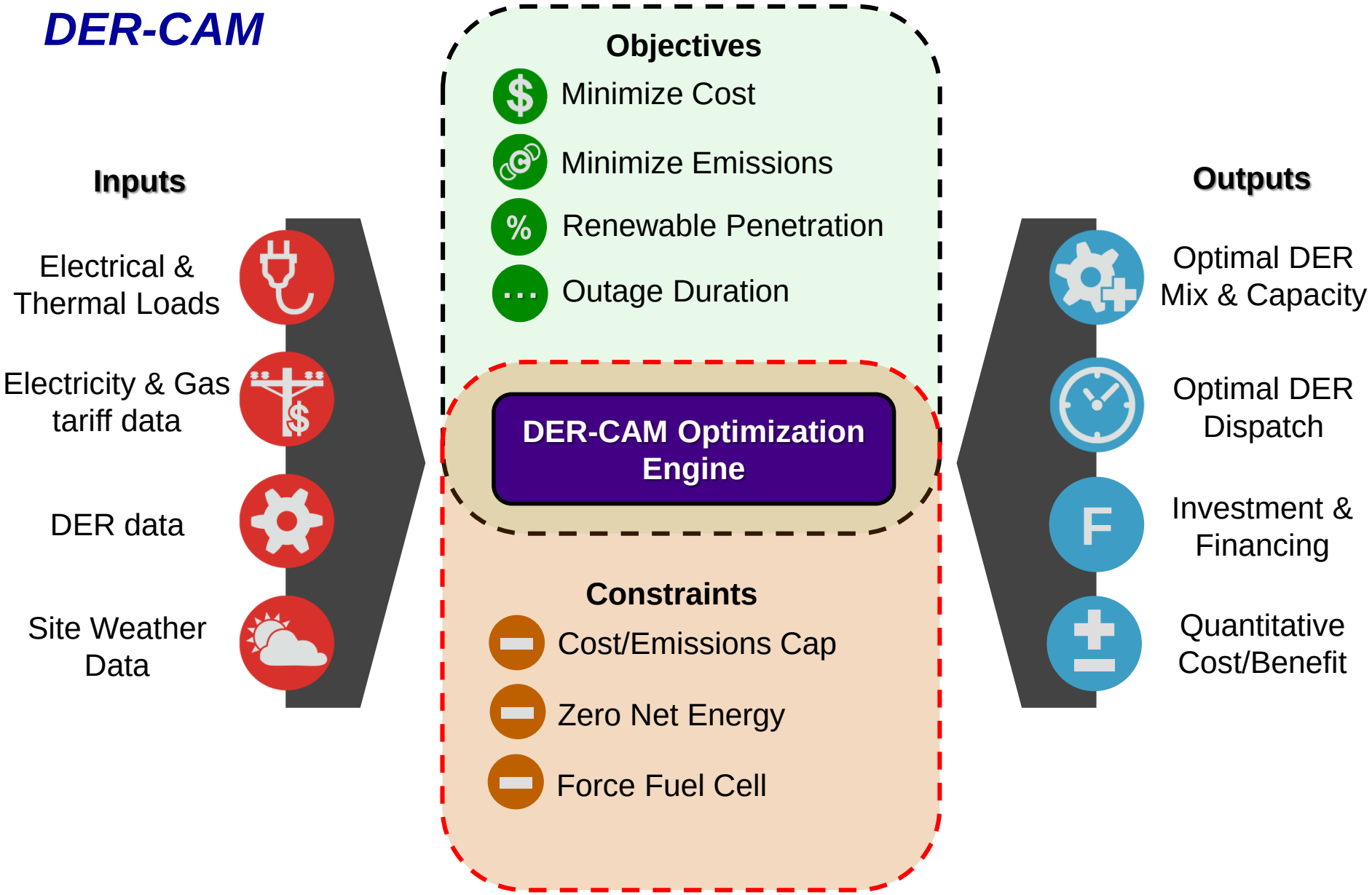
- Network R and X impedances
- Load power factors
- Generator power factors
- Load locations





An Illustration

Modeling Tools
DER-CAM



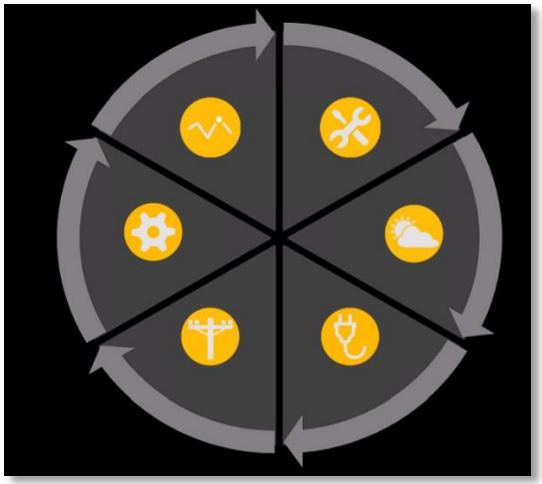
Modeling in DER-CAM
Sample Case

- Basic data requirements:

Data Needed	Data Source
Electrical Load	Serving utility
Thermal Load	Serving utility
Electrical/Fuel tariffs	Serving utility(s)
DER technical specifications, price points	Market research, Manufacturers
Weather (irradiance, wind speed, temperature, etc.)	PVWatts, weather stations, EPRI

- Customer information:
  - Willingness to provide demand response (load shifting/curtailment)
  - Value of Loss Load (VOLL)
- Modeling objective

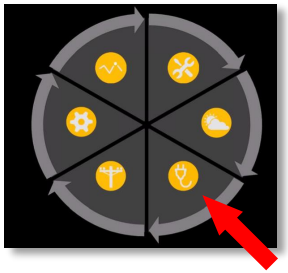
Modeling in DER-CAM
Sample Case (Cont.) – Background



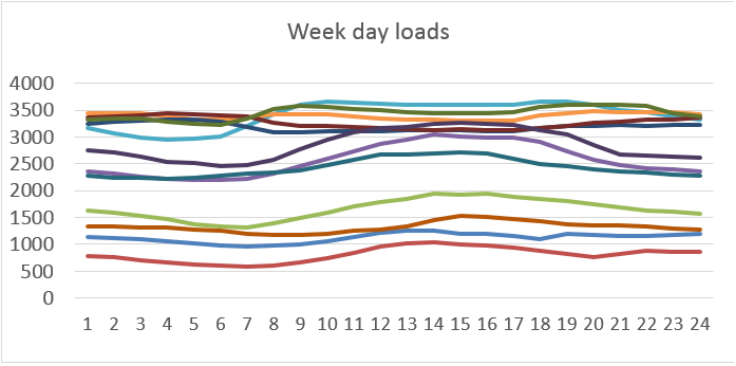
DER-CAM DECISION SUPPORT TOOL FOR DECENTRALIZED ENERGY SYSTEMS
ANALYTICS | PLANNING | OPERATIONS

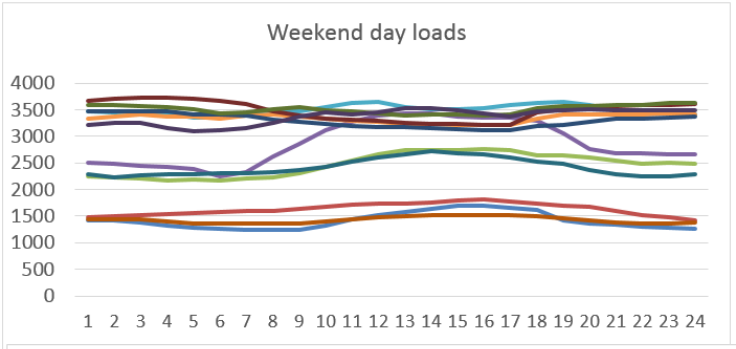
- Hospital
  - 5 floors
  - 241,351 (ft^2) total area
- Location: Jackson, Mississippi
- Utilities: Entergy, Atom Energy
- Loads: electric, cooling (electric), heating (gas)
- Existing assets: grid, HVAC, boiler, diesel genset
- Objectives:
  - Cost minimization
  - 1 week outage duration
  - 100% load served
  - 10% renewable penetration

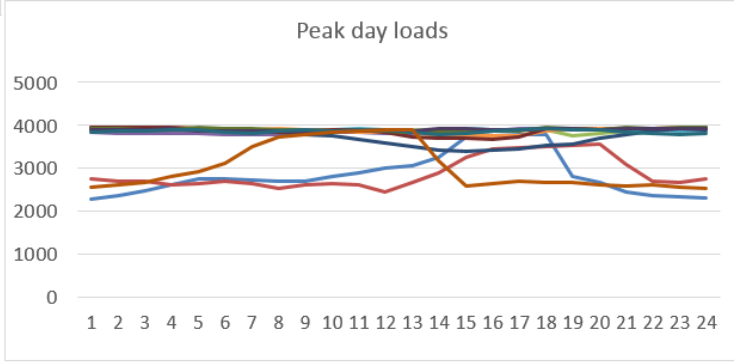
Modeling in DER-CAM
Sample Case (Cont.) - Loads



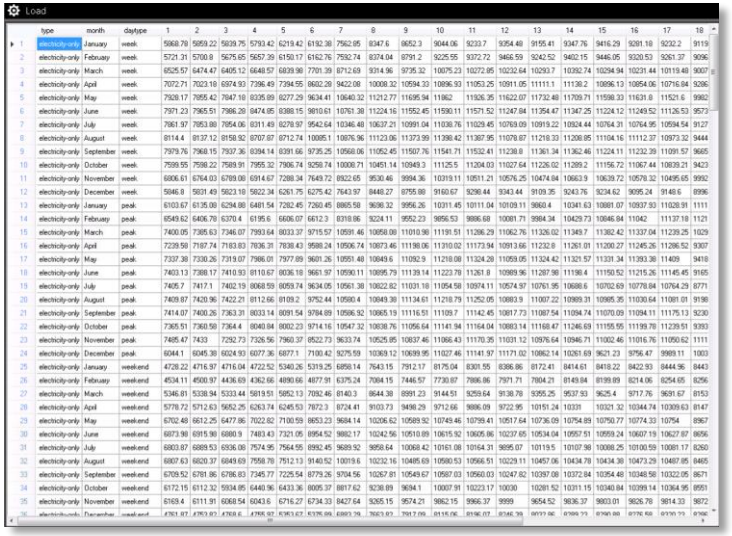
Loads







Data Processing



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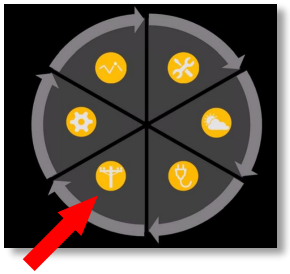
Modeling in DER-CAM
Sample Case (Cont.) - Tariffs



Entergy Large Commercial Tariff

ENTERGY MISSISSIPPI, INC

Date Filed: December 30, 2014
Date to be Effective: January 30, 2015
Docket No.: 2014-UN-132

MISSISSIPPI PUBLIC SERVICE COMMISSION
P.S.C. Schedule No. I-14
Revised Schedule No. 14, Date: January 30, 2015
Superseded Schedule No. 14, Date: December 31, 2002
Schedule Consists of: Three Pages

LARGE GENERAL SERVICE RATE SCHEDULE C-28

NET MONTHLY RATE

A. RATE

$4,715.18	for the first 1,000 kW or less of Customer's Demand
$ 4.644	per kW for all additional kW of Customer's Demand
$ 0.056330	per kWh for the first 435,000 kWh
$ 0.053071	per kWh for additional kWh up to 400 kWh per kW of Customer's Demand
$ 0.050679	per kWh for the next 350,000 kWh
$ 0.047538	per kWh for all additional kWh
$ 0.47	per KVAR of Excess KVAR

V. CUSTOMER'S DEMAND

The average kW supplied during the fifteen-minute period of Customer's greatest use in the Day Hours (Day Load) of the current month plus 25% (for Primary Service) or 33 1/3% (in all other cases) of the amount by which the average kW supplied during the fifteen-minute period of Customer's greatest use in the Night Hours (Night Load) of the current month exceeds the Day Load, but not less than the highest of the following:

(1) 80% of the highest kW so established in the prior eleven months, or

(2) the minimum kW provided in the Agreement for Service, or

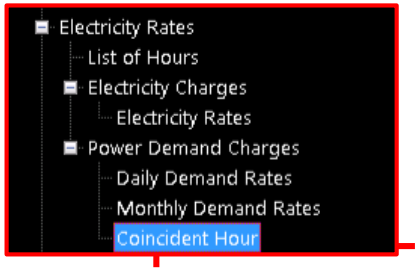
(3) 1,000 kW.

If the instantaneous load exceeds the highest average fifteen-minute load by an unusual amount, such instantaneous load may be taken as the demand used for billing.

DAY HOURS
Initially 7 a.m. to 9 p.m. C.S.T. (8 a.m. to 10 p.m. C.D.T.) Monday – Friday except holidays. These hours are subject to change by the Company upon thirty days' written notice, but shall not exceed fourteen hours per day.

NIGHT HOURS
All hours not designated as day hours.

Data Processing



Electricity Rates

	F1	On	Mid	Off
1	January	0	0	0.063
2	February	0	0	0.063
3	March	0	0	0.063
4	April	0	0	0.063
5	May	0	0	0.063
6	June	0	0	0.063
7	July	0	0	0.063
8	August	0	0	0.063
9	September	0	0	0.063
10	October	0	0	0.063
11	November	0	0	0.063
12	December	0	0	0.063

Coincident Hour

	F1	F2
1	January	18
2	February	18
3	March	18
4	April	18
5	May	18
6	June	18
7	July	18
8	August	18
9	September	18
10	October	18
11	November	18
12	December	18

Daily Demand Rates

	F1	coincident	noncoincident	onpeak	midpeak	offpeak
1	January	0	0	0	0	0
2	February	0	0	0	0	0
3	March	0	0	0	0	0
4	April	0	0	0	0	0
5	May	0	0	0	0	0
6	June	0	0	0	0	0
7	July	0	0	0	0	0
8	August	0	0	0	0	0
9	September	0	0	0	0	0
10	October	0	0	0	0	0
11	November	0	0	0	0	0
12	December	0	0	0	0	0

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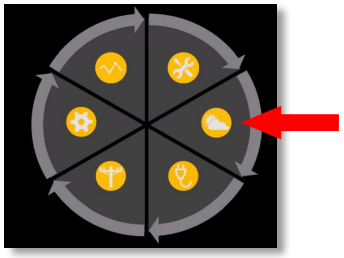
Modeling in DER-CAM
Sample Case (Cont.) – Site conditions

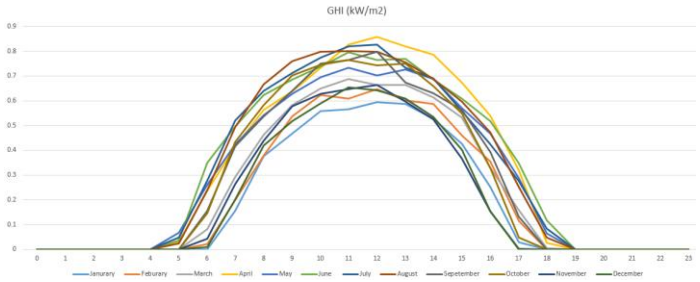


PVWatts

Location and Station Identification

Requested Location	University in Jackson, Mississippi	
Weather Data Source	(TMY3) JACKSON INTERNATIONAL AP, MS	5.2 mi
Latitude	32.32° N	
Longitude	90.08° W	

GHI



Data Processing

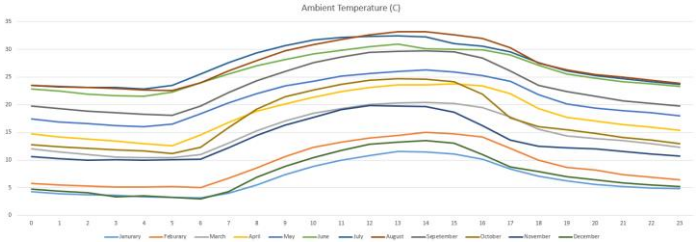
Solar Insolation

	month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	january	0	0	0	0	0	0	0.0051	0.0675	0.2036	0.3174	0.3599	0.3447	0.2932	0.2417	0.1397	0.0466	0.0022	0	0	0	0	0	0	0
2	february	0	0	0	0	0	0	0.031	0.1279	0.271	0.3886	0.4298	0.4275	0.4079	0.3551	0.2438	0.1283	0.0257	0	0	0	0	0	0	0
3	march	0	0	0	0	0	0.0135	0.096	0.247	0.3629	0.4983	0.5892	0.6097	0.5576	0.4723	0.3579	0.2243	0.0829	0.0075	0	0	0	0	0	0
4	april	0	0	0	0	0.007	0.0624	0.2072	0.3496	0.4774	0.5665	0.6203	0.6204	0.6491	0.5601	0.3991	0.2527	0.1218	0.0243	0.0003	0	0	0	0	0
5	may	0	0	0	0	0.0231	0.1077	0.246	0.3936	0.5725	0.6814	0.7461	0.7612	0.6841	0.6102	0.4742	0.3018	0.164	0.0494	0.0041	0	0	0	0	0
6	june	0	0	0	0.0037	0.0331	0.1343	0.289	0.4441	0.5588	0.7289	0.7903	0.8289	0.7964	0.6843	0.5467	0.4092	0.2258	0.0786	0.0173	0	0	0	0	0
7	july	0	0	0	0.0008	0.0233	0.1095	0.2403	0.4068	0.5665	0.6696	0.7407	0.8302	0.7646	0.6341	0.5207	0.3646	0.2059	0.0804	0.0157	0	0	0	0	0
8	august	0	0	0	0	0.0116	0.0794	0.2226	0.3667	0.4985	0.6219	0.6892	0.7136	0.6949	0.6244	0.4714	0.319	0.1587	0.0441	0.0045	0	0	0	0	0
9	september	0	0	0	0	0.0001	0.039	0.1665	0.3256	0.4753	0.5993	0.6116	0.6617	0.5467	0.4745	0.3498	0.2151	0.0775	0.0046	0	0	0	0	0	0
10	october	0	0	0	0	0	0.0141	0.0984	0.2375	0.3653	0.4355	0.4556	0.4678	0.4088	0.3571	0.2245	0.095	0.0147	0	0	0	0	0	0	0
11	november	0	0	0	0	0	0.0001	0.0318	0.1263	0.2119	0.2906	0.3379	0.3088	0.2831	0.2132	0.1184	0.0309	0	0	0	0	0	0	0	0
12	december	0	0	0	0	0	0	0.0059	0.0655	0.1559	0.2697	0.3081	0.32	0.2709	0.2052	0.1082	0.0228	0	0	0	0	0	0	0	0

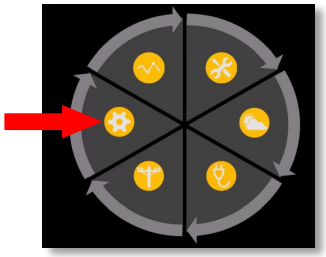
Ambient Hourly Temperature

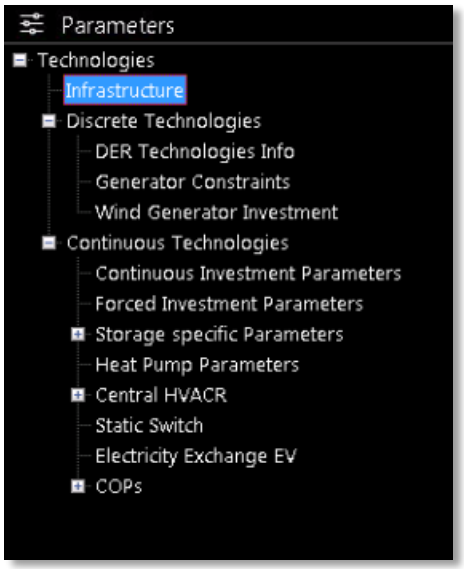
	F1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.6	1.5	2	2.2	2.1	1.2	
4	April	8.6	6.3	4.3	3.1	2.4	1.7	1.1	0.9	0.7	0.1	0	0	0	0.8	3	5	6.8	8.1	9.2	9.9	10.4	10.7	10.6	9.6
5	May	15.7	14	11.9	10.6	9.6	9.1	8.6	8.1	7.4	6.9	6.4	6.4	7.5	9.6	11.5	13.1	14.2	15.1	15.9	16.6	17	17.1	17.1	16.4
6	June	19.2	17.9	15.8	14	13	12.5	12.1	11.8	11.5	11.3	11.1	11	12.2	14	15.3	16.5	17.6	18.5	19	19.5	19.9	20	20	19.8
7	July	24.6	22.4	19.7	17.9	17	16.2	15.6	14.9	14	13.4	12.6	12.2	13.6	16.6	19.4	21.4	23	24.1	25	25.8	26.5	26.8	26.7	25.9
8	August	23.6	21.2	18.9	17.7	17	16.6	16.1	15.5	15.1	14.8	14.4	14.2	14.4	16.2	18	19.8	21.2	22.8	24.1	24.8	25.2	25.4	25	24.7
9	September	17.4	14.5	12.7	11.8	11.1	10.5	10	9.3	8.8	8.3	7.9	7.4	7.2	8.8	12.1	15.1	17.1	18.5	19.6	20.3	20.6	21	20.8	19.9
10	October	10	8.2	7.1	6.4	6.1	5.6	5.3	4.7	4.1	4	3.9	3.8	3.5	3.7	6.4	9.6	11.7	13.3	14.5	15.3	15.6	15.3	14.7	13
11	November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.4	0.3	0	0	
12	December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0.7	1.1	0.9	0	0	

Ambient Temperature



Modeling in DER-CAM
Sample Case (Cont.) - DER





- Existing
- New
- Force

Renewable Gen

- Solar Photovoltaics

Fossil Fuel Gen

Microturbine

- Max Power (kW)
- Sprint capacity (% of power)
- # of sprint hours (hours)
- Fuel type
- Efficiency (ratio)
- CHP capable? (yes/no)
- Alpha (power to heat ratio)
- NOx emissions rate (kg/hr)
- Maximum annual operating hours (hours)
- Minimum loading (% of power)

- Capital cost ($)
- Lifetime (years)
- O&M fixed costs ($/year)
- O&M variable costs ($/year/unit)
- NOx treatment costs ($/kg)

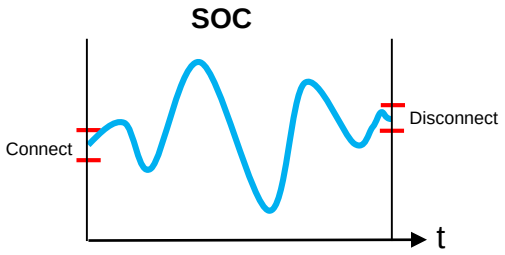
Solar Photovoltaics

- Module rating (kW DC)
- Module Size (m2)
- Efficiency (%)
- Inverter size (
- Total land are

- Capital cost ($
- Lifetime (year
- O&M fixed co
- O&M variable

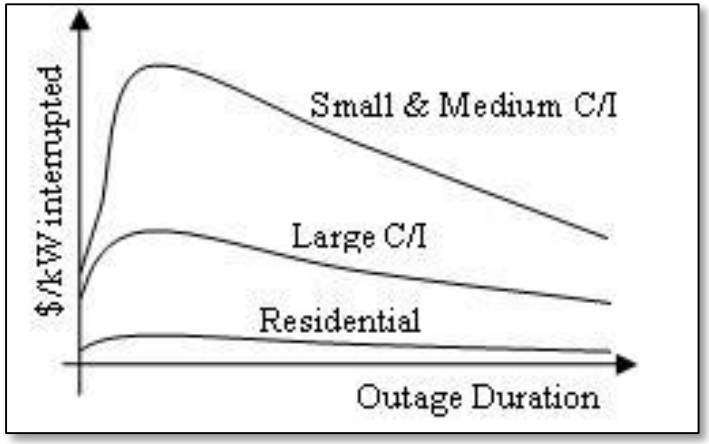
Electric Vehicles

- Multiple locations
- Min connect/disconnect SOC
- Max charge hours
- Battery size
- Efficiency
- Decay
- etc.



Modeling in DER-CAM
Sample Case (Cont.) - Scenario

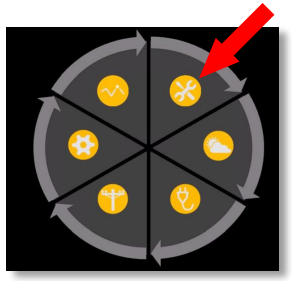
- Outage duration, time
- Value of Loss Load = $ per kwh not served
  - Customer, time dependent



ICECalculator.com
Interruption Cost Estimate Calculator
U.S. DEPARTMENT OF ENERGY

- Customer preferences
  - How much load can be shifted, within what period
  - How much load can be curtailed, at what price
  - How much load can be curtailed, under an emergency (non-critical)

Modeling in DER-CAM
Sample Case (Cont.) - Parameters



interest rate

cap cost/emission

multi-objective cost/emission

renewable penetration

net metering

CO2 Tax

ZNEB constraint

EnergyPlus building retrofit

Parameters Table

	F1	F2
1	IntRate	0.05
2	Standby	0
3	Contrct	0
4	turnvar	0
5	CO2Tax	0.272727
6	macroeff	0.34
7	cooleff	0
8	BaseCaseCost	50000000
9	BaseCaseCO2	50000000
10	MaxPaybackPeriod	10
11	FractionBaseLoad	0.5
12	FractionPeakLoad	0.1
13	ReliabilityDER	0.9
14	MaxSpaceAvailablePVSolar	1620000
15	PeakPVEfficiency	0.1529
16	MultiObjectiveMaxCosts	9000000
17	MultiObjectiveMaxCO2	4400000
18	MultiObjectiveWCosts	0.6
19	MultiObjectiveWCO2	0.4
20	ZNEBsolarAreaMultiplier	200
21	ZNEBCostsMultiplier	2
22	BldgShellLifetime	20
23	MinAnnDERGen	0
24	MinAnnRENGen	0
25	MaxAnnDERGen	100
26	MaxExportkW	10000

Options Table

	F1	F2
1	DiscreteInvest	1
2	ContinuousInvest	0
3	DFChillInvest	0
4	WindInvest	0
5	SwitchInvest	0
6	NonPVSales	0
7	PVSales	0
8	NetMetering	0
9	InvestmentConst	0
10	StandbyOpt	0
11	VaryPrice	0
12	DisableCHP	0
13	CO2Tax	0
14	MinimizeCO2	0
15	ZNEB	0
16	MultiObjective	0
17	DiscreteElecStorage	0
18	LS	0
19	CentralHVACR	0
20	CentralHVACRInvest	0
21	GSHPAnnualBalance	0
22	FuelCellConstraint	0
23	BuildingWallInvest	0
24	BuildingWindowInvest	0
25	BuildingDoorInvest	0
26	BuildingRoofInvest	0
27	BuildingGroundInvest	0

Modeling in DER-CAM
Sample Case (Cont.) - Steps

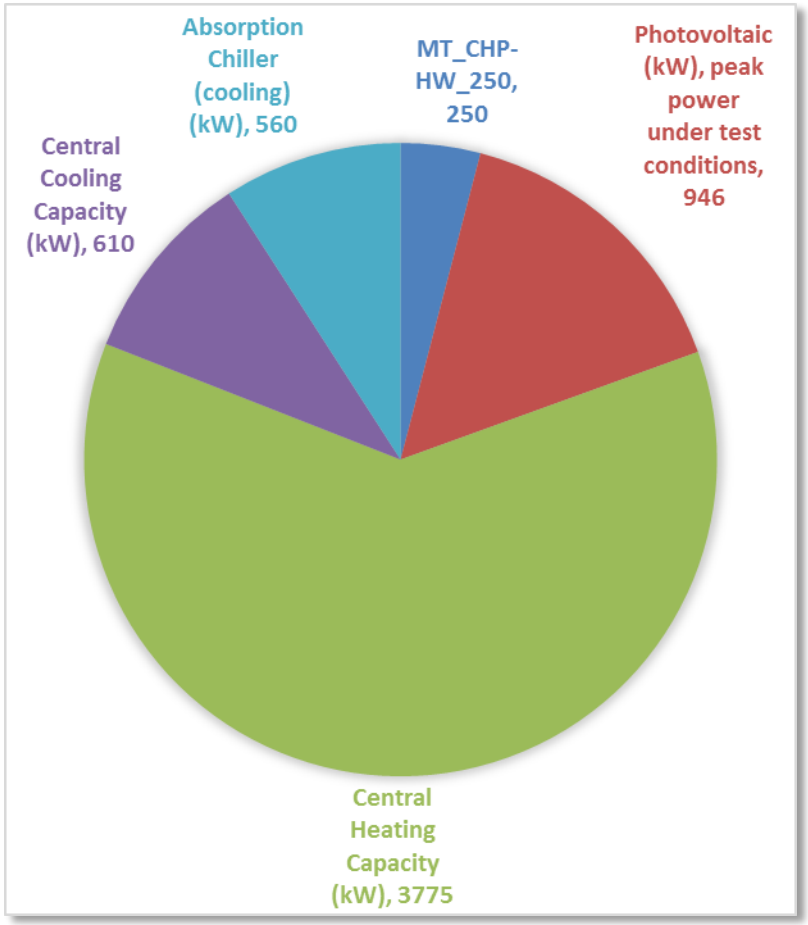
1. **Create base case w/ outage**
   - Assets: Grid, HVAC, boiler, diesel (backup)
   - Enable curtailment during outage
   - Calculate total value of loss load

2. **Obtain base case cost & emissions**

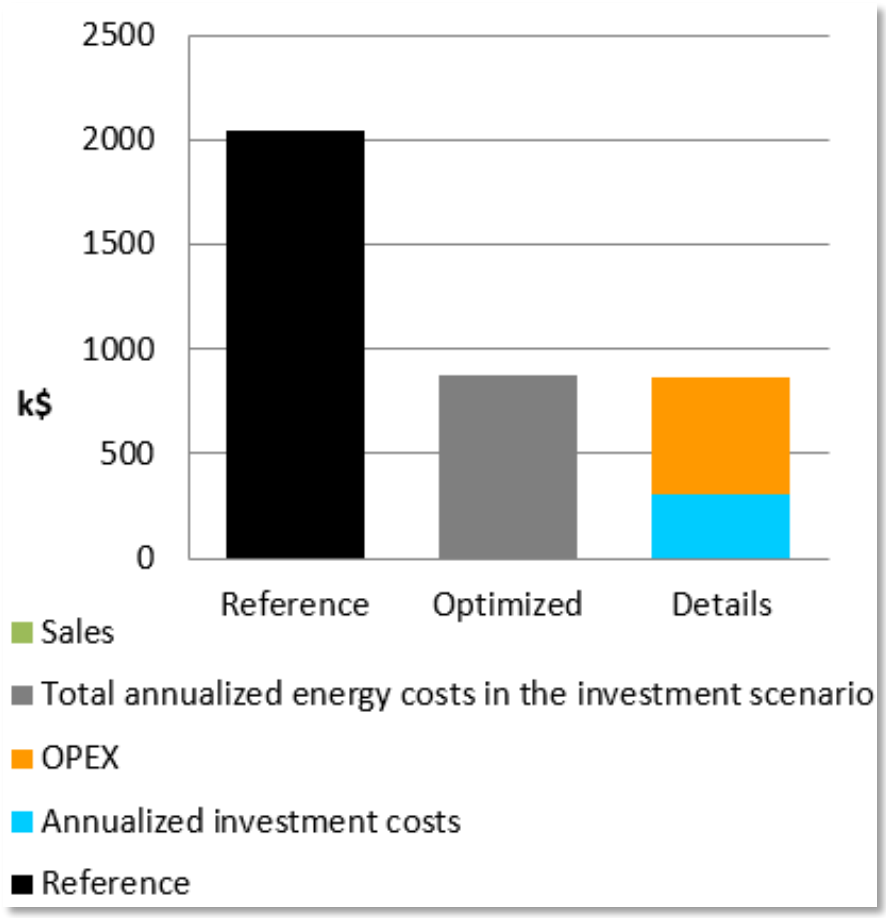
3. **Create investment case w/ outage**
   - Possible new assets: Grid, PV, electric storage, gensets, microturbines, fuel cells, CHP, and absorption chillers.
   - Use base cost & emissions as cap
   - No curtailment

Modeling in DER-CAM
Sample Case (Cont.) - Results

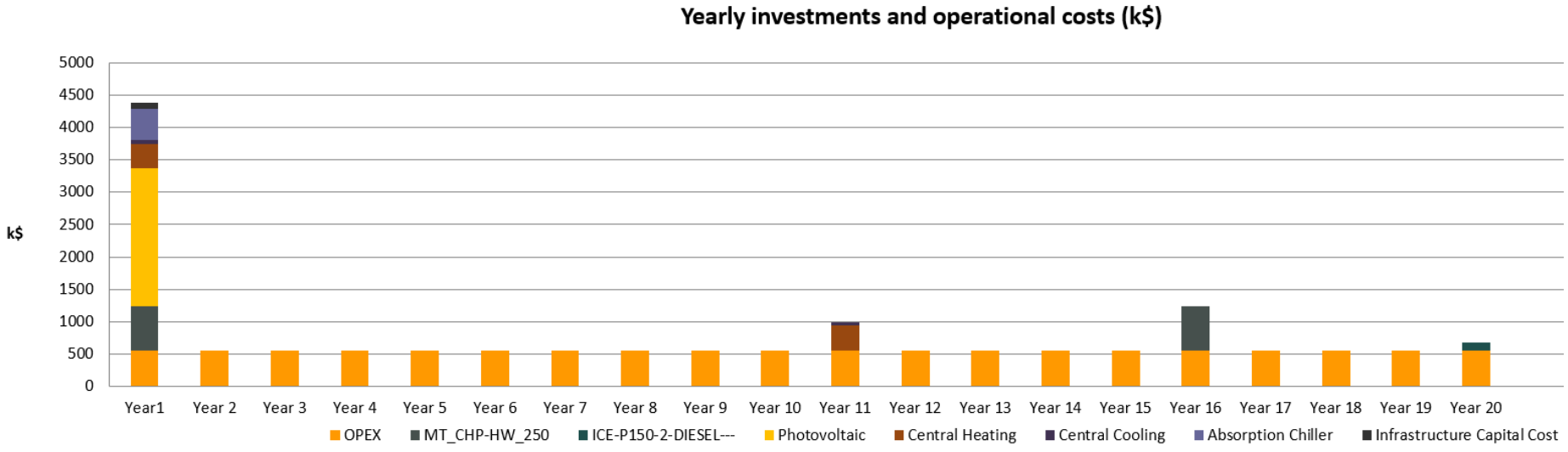
DER Investments (kW)

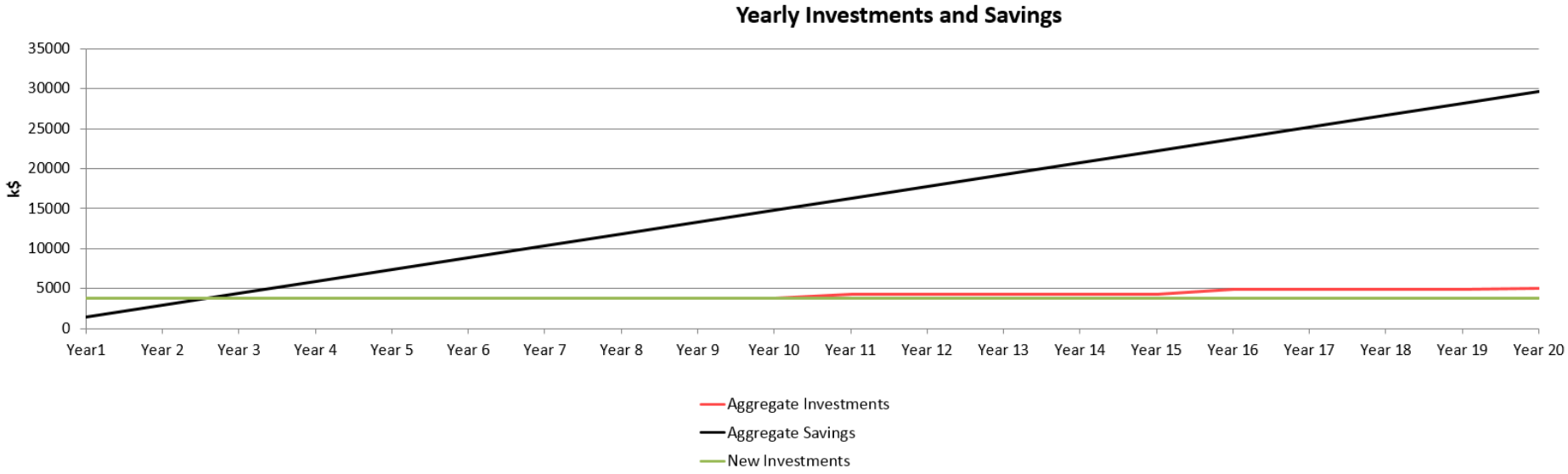


Annualized Cost (k$)

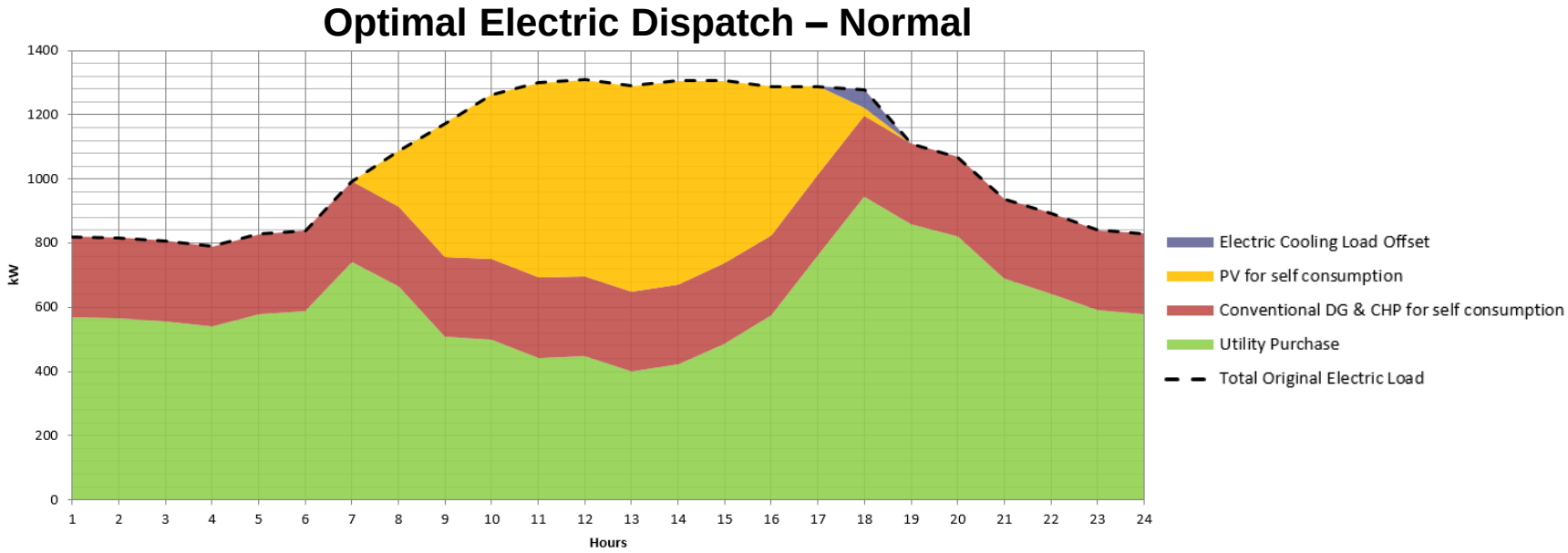


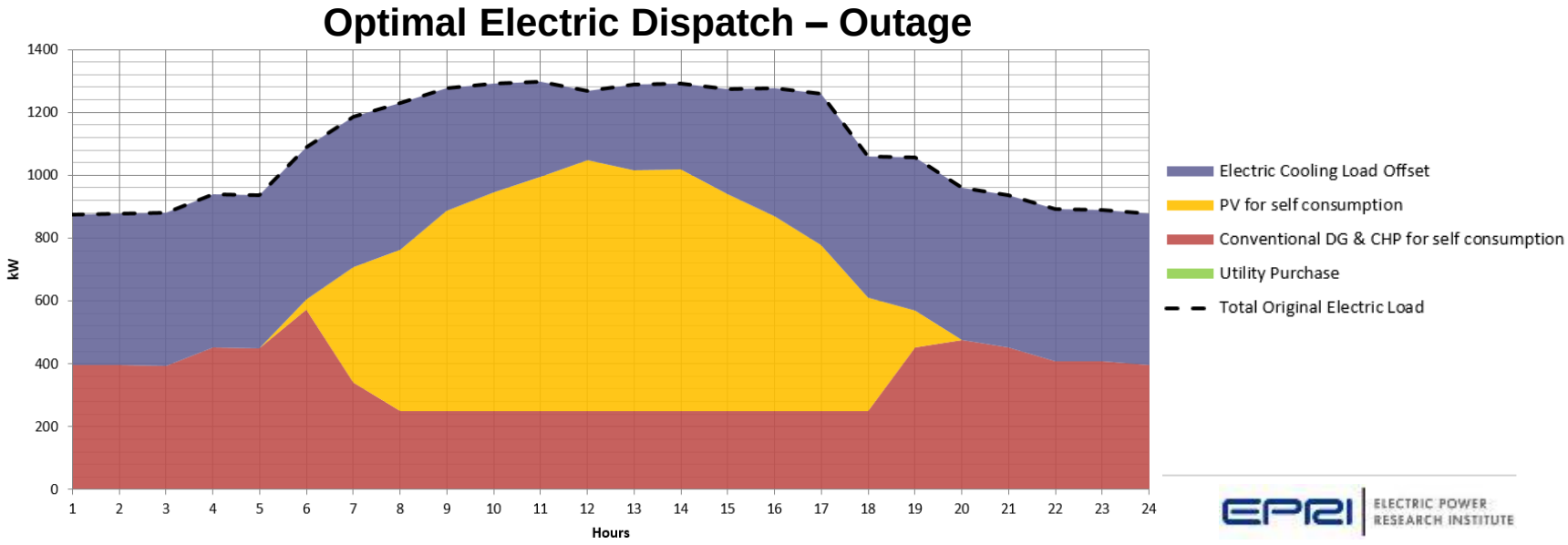
Modeling in DER-CAM
Sample Case (Cont.) - Results



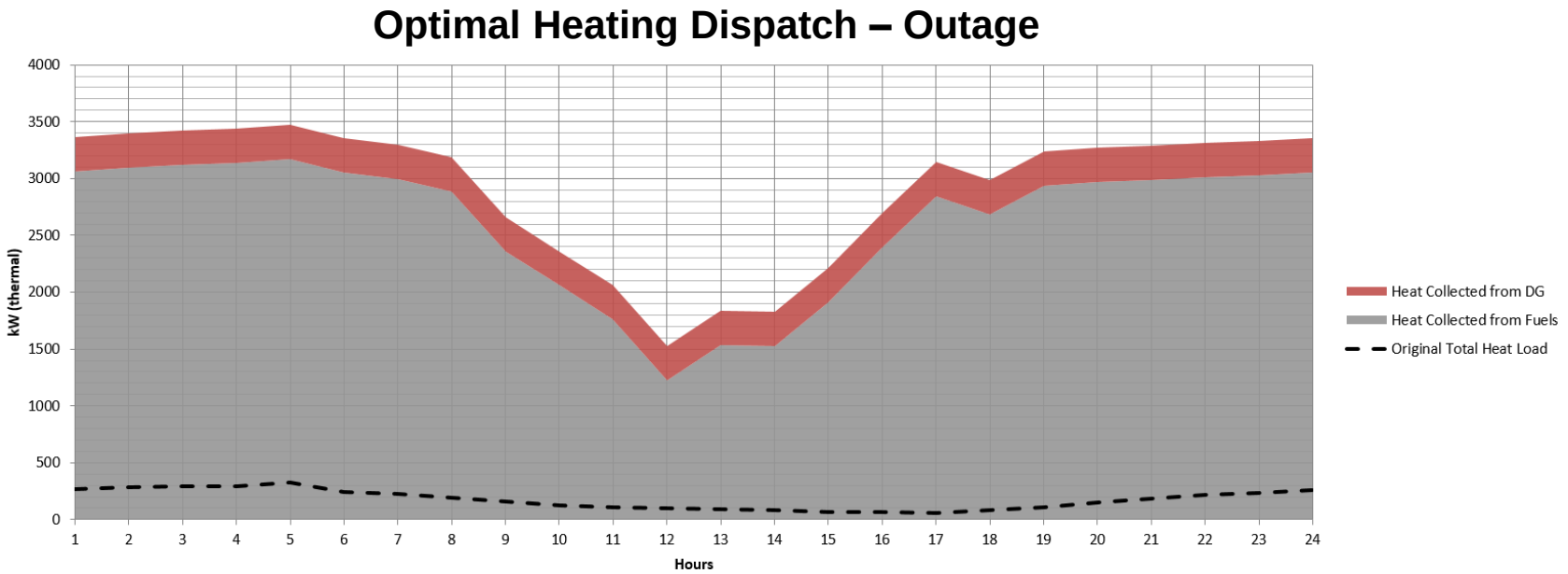


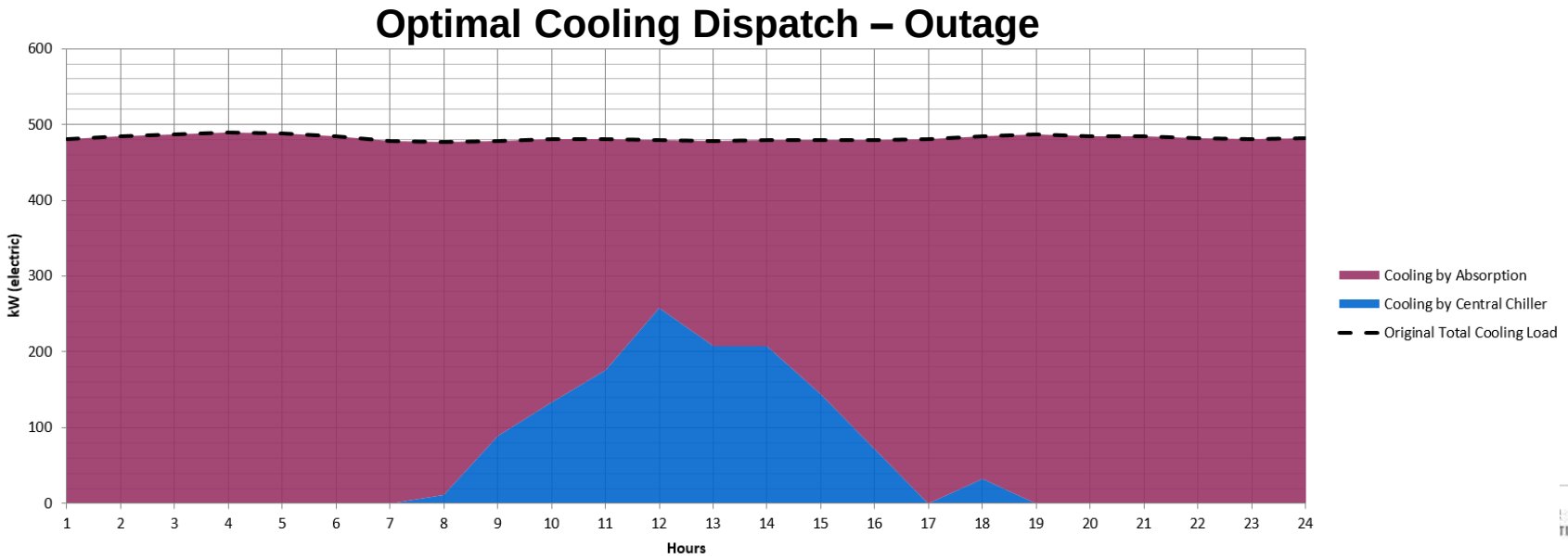
Modeling in DER-CAM
Sample Case (Cont.) - Results





Modeling in DER-CAM
Sample Case (Cont.) - Results





EPRI & LBNL Collaboration

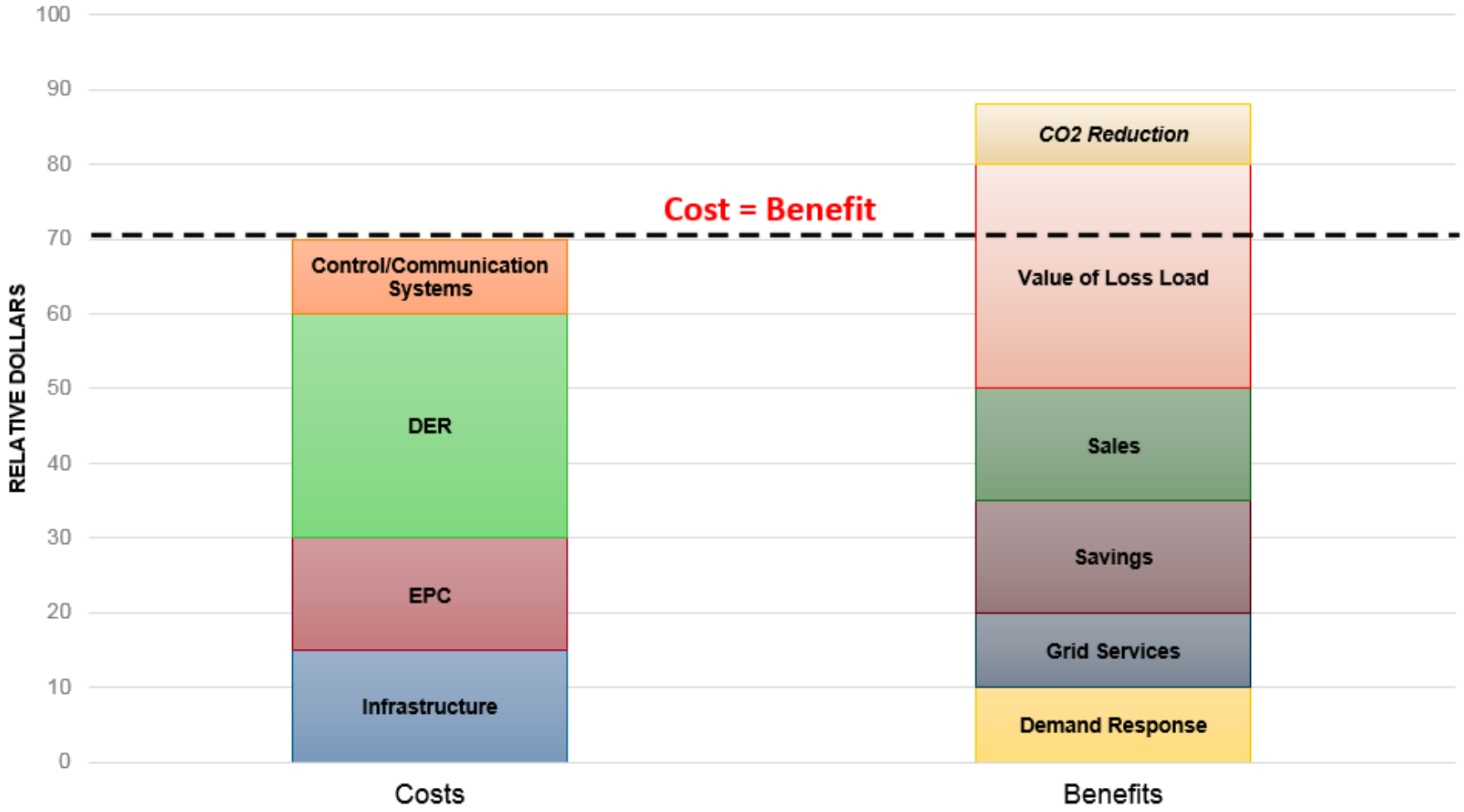
- Beta Testing
- Real-world modeling needs
- Projects

- Training
- Debugging
- Features implementation

New & Upcoming Features

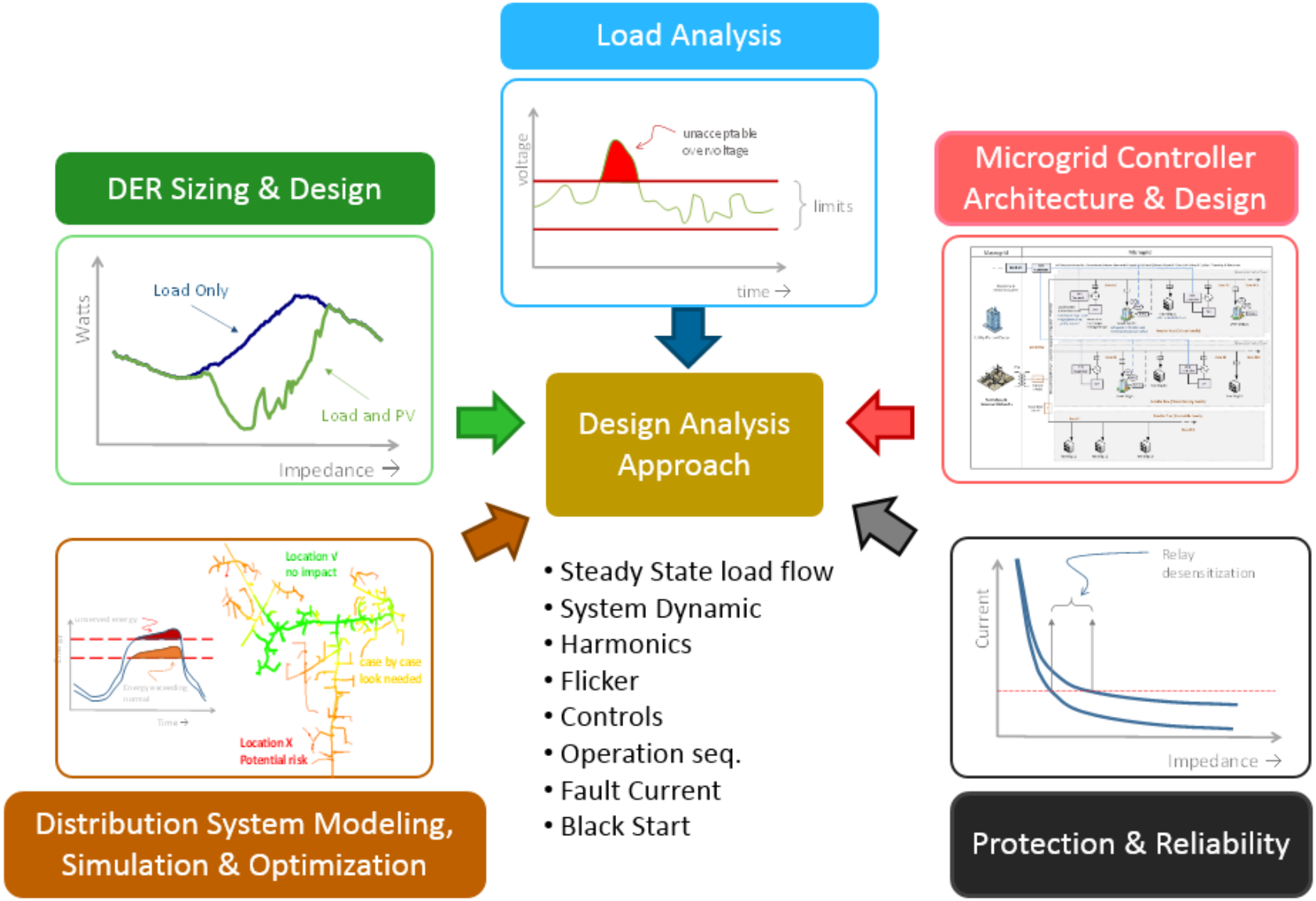
- Nodal network modeling
- 15-min time steps
- Operating reserve
- Demand response
- Thermal load shifting incl. pre-heating/cooling

Cost-Benefit Analysis



An Illustration

Phase II: Detailed Design…



EPRI ELECTRIC POWER RESEARCH INSTITUTE

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Together…Shaping the Future of Electricity

Appendix

EPRI Microgrid Project Portfolio

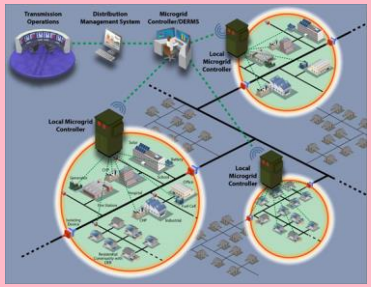
DOE Funded

Microgrid Controller

- R&D
- Vendor Partnership
- Lab Testing, Field Trial

Communications

- Microgrid Controller and DERMS requirements
- Architecture



Utility Collaboration

Feasibility Study

- Host Community
- BCA

Detailed Design

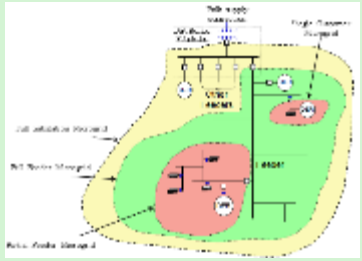
- Host Community
- Modeling

Technical Specification and Guide

Integrated Grid Pilot

- Field Trials
- Demo
- Performance Evaluation
- BCA analysis
- Integration Guides
- Communications, Cyber Security & Privacy

Utility Level Engagement



Base R&D